THOMPSON (C. O.)

INAUGURAL ADDRESS.

THE MODERN POLYTECHNIC SCHOOL

INAUGURAL ADDRESS

OF

PRESIDENT CHARLES O. THOMPSON

DELIVERED AT THE OPENING

OF THE

ROSE POLYTECHNIC INSTITUTE

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ADDRESS.

The Rose Polytechnic Institute is a school of technology. In order to understand the functions of the school it is necessary to take a brief survey of the field of technical training. This phrase describes all those forms of training youth which deal with the application of art or of science to the industrial arts. Those schools in which designing for the patterns of textile fabrics, or for the decoration of wood, iron, pottery, gems, etc., is the principal end, are called art schools, or schools of design, of which the South Kensington system is the most famous example; all those in which the principles of physical science are studied with reference to their application to the solution of practical problems in building, machine construction, and design, or in civil engineering, are called polytechnic or technological schools. There is great confusion just now in the use of terms, technical education being used to describe all that which aims at a directly practical end as opposed to the education given at the college; while that part of it which does not deal with ornament or textile design is sometimes described by the same term. The word technology, which formerly signified the terms used in the sciences, now means the application of the sciences to industrial ends. The term polytechnic, originally used to describe schools of technology, has refused to yield to the more desirable synonym, technological, partly because it is an easier word, and partly because it contains a suggestion of the many-sidedness of the subject which the better word lacks. There is no good word corresponding to polytechnic or technological to apply to the persons who practice the profession indicated, and so these persons are called, now as always, engineers, and the business engineering. A few still cling to the term scientific schools in speaking of these institutions. In the present prevailing confusion of terms the best that can be said is that a polytechnic school teaches technology to engineers. Below the grade of the polytechnic there are multitudes of schools and parts of schools that teach the elements of the mechanic arts—many of

them of the greatest interest and importance—and around it are many institutions that devote themselves to industrial art; but I must deny myself the pleasure of discussing any of these, with the important collateral questions of policy that they present, and proceed at once to the school we have in hand—the polytechnic. We shall find that all schools of technology, under whatever names, or with whatever special aims, present a common system of instruction complete in itself, with strenuous requisitions, a logical curriculum and a sharply defined end. In treating of technology, I am happily absolved from the duty of pointing out its importance; that is settled by the establishment of this school and others like it by the men who endowed them. They were men whose sagacity was too strong to be mistaken.

Technology is essentially a new idea; it is certainly no older in its present aspects than the discovery of the law of the conservation of energy—the great idea of the present century. No discovery since that of gravitation has been so stimulating or so powerful. Its influence is incalculable. It is seen in the multiplication of labor-saving machinery for every form of work, the great array of useful inventions, the expansion of the system of land and ocean highways, and especially in the immense increase of the means for acquiring knowledge. This demand for economy of force and material has brought about great changes in the industrial arts; the apprentice system has disappeared; the necessaries of life being made by machinery, manual trades are no longer needed for that end, and skilled handicraft is a rare accomplishment. There is and there will always be a demand for skilled labor in the arts of building-construction, in pattern-making and similar forms of wood-work, in die-sinking and kindred arts that deal with the metals, and especially in assembling and finishing the parts of structures as they are delivered from machines; but this is a small demand compared with what existed when shoes, clothes, furniture and tools were made by hand. The mechanic of the future will be a machinist. To such an extent is this replacement of handicraft by machinery true that we have shoemakers who cannot make a shoe, chairmakers who cannot make a chair, and generally artisans ignorant of the whole of any art. Mr. Batchelder, of North Brookfield, Mass., the largest shoe manufacturer in Worcester county, said that out of his six hundred men not more than ten could make a shoe. I once examined a very interesting picture of some pieces of iron that had been done by boys in an

experimental forge-shop; the work seemed to be well done and creditable to the workmen; but out of some seventy pieces not more than ten would ever be made by hand at all in actual manufacturing.

Another result of the economy of force is that attention is concentrated now more upon the principles of phenomena than upon the phenomena themselves. Formerly the only hope of finding a better or cheaper way of doing things lay in the chance discoveries of ingenious men—men looked at things from the outside in; now it is seen that nothing is so fruitful and that nothing so advances human interests as a principle—men look at things more from the inside out. For, nearly all mechanical ways of doing things were once regarded as out of the ordinary course of human affairs and to be relegated, if not to the domain of the supernatural, at least to that of the superhuman. The feeling towards scientific investigation as a means to practical ends partook of the same quality that infested men's views of disease; if typhoid fever prevailed in a given district the people did not look to their drains and wells, but flocked to church and appointed a day of fasting. What were regarded as the pardonable vagaries of Daniel Treadwell, Rumford Professor in Harvard University, turn out now to be the inventions upon which single-track railroads, the machinery for spinning cordage-yarn, the Armstrong, Blakely and Krupp cannon depend. I will venture, however, the assertion that no person in this audience ever heard before of these great inventions as Treadwell's; they came too soon for the world to know them as works of genius, yet they are the first fruits of the new era in which great problems are solved, not by happy inventions of geniuses real or affected, but by the sober and steady application by laborious scholars of established principles of physics.

Time would fail me to enumerate the influential inventions that have sprung from a similar origin. Who has not heard of the Siemens' Furnace, the Bessemer Converter, dynamite, compressed air and the uses of electricity? And it must also be remarked that each of these inventions demands corresponding machinery of novel design; for another feature of the new era is the necessity of reconstructing old machinery in more economical forms and the constant call for new machinery to meet new demands. When a new invention is made nowadays, machinery for it is as important as the invention itself. Perhaps the most striking illustration of

the change in common things which has been brought about by technology is the rail on which railway traffic is conducted; formerly it was an iron edge rail, supported by chains and having more iron in the base than the head; clumsy as this rail was, it was claimed to be the only form in which the only available metal could be used for the purpose; now the rail is made of steel, with well defined tread, web and base, the principal weight of metal in the head, where it is most needed, and every line subjected to the finest physical tests. To those who know how much of the best knowledge we have of physics and chemistry has been put, and is still put into a railroad rail, it seems one of the most interesting of all modern manufactures. It is not wide of the mark to characterize the past age as one of invention, the present as one of engineering. The study and mastery of the principles of physical science, the ability to express those principles in drawing and descriptions and to apply them to the solution of practical problems through machinery and handicraft are the essential qualities of an engineer. So that a polytechnic school, by whatever name called, technological, technical or engineering, teaches technology to engineers, i. e., it teaches the principles of physical science and their application to the industrial arts.

Engineering is the term that includes all the arts of production and construction which arise from the physical sciences. Its object is to bend the forces of nature to the service of man.

The names applied to the different branches of engineering are not always appropriate, but in general, a civil engineer constructs public works, such as highways, railroads, water works, sewers, etc.; a mechanical engineer deals with machinery, from the original design of each part, through the machine shop and into the structure and to the operation of the structure, i. e., the machine; the chemical engineer applies chemistry to the manifold products that result from the play of chemism. Then there are numerous fields which the term covers: as hydraulic, steam, gas, electrical engineering. In each and all, the engineer is distinct from the artisan or craftsman by exactly the amount of his knowledge of the scientific principles which underlie the practice of his profession and his resulting ability to apply those principles to the ready and complete solution of real problems as they arise.

For example: Mr. Batterson had occasion to cut a block of marble so as to produce a warped surface, for which his workmen had no patterns; the men had great skill in stone cutting, but

could not cut that stone. A graduate of a school of technology happened to be employed in the city schools as teacher of drawing; hearing of the case at the marble yard, he tendered his services, applied the familiar principles of stereotomy, made patterns, and the men at once executed the work. Last November the Italian government made comparative tests of the power of different armor-plates to resist the shot of heavy ordnance; the plates that stood the test were made by Schneider, at the shops of the French technological school at Le Creusot.

The bridge over the Vistula river, at Warschau, was built by a graduate of Carlsruhe; that over the Volga, by English engineers; but the latest, largest and most costly bridge in Russia—over the Neva—was built by graduates of the Imperial Technological school of St. Petersburg, and every piece of iron that entered into it was tested in the laboratories of that school.

A few years ago it became suddenly desirable and important to pump out the central shaft of the Hoosac Tunnel; a suction pump was plainly inadmissible; the craftsmen had nothing to suggest; a young engineer built a small raft on the surface of the water in the shaft, lowered on to it a steam pump, set his boiler at the shaft mouth, had himself lowered to the raft, and alone in the darkness worked his pump twenty-six hours without accident and with great efficiency; men then tendered their services in abundance, and the problem was soon solved.

But the air is full of modern instances of the triumphs of engineering skill in overcoming great natural obstacles; the use of the inclined plane in the zig-zag roads over which horses trot in safety and at ease from Alpine heights to the valleys below; the application of compressed air to the two purposes of sinking caissons and driving machines at a great distance from the source of power, the use of the friction clutch, the air-brake, and a thousand other examples of the application of the familiar principles of science to the solution of mechanical problems. In each case, however, it will be noticed that one man may understand physics thoroughly, as thousands of men have understood the subject, and another man may understand the construction of machinery, but not one of the triumphs of engineering above mentioned be achieved. The theoretical knowledge of physics and the practical command of machinery must come together; if this happy conjunction occur in one and the same man, the best results follow. Then the same affluent good comes forth in the domain of mechanics that

abounded in the middle ages, where the artist and artisan were one; when Peter Vischer and Quentin Matsys worked at blacksmithing, and Michael Angelo cut stone, and Benvenuto Cellini hammered silver and gold, each touching the iron, or the stone, or the silver, with a beauty and value that all the ages since have only enhanced.

Here some one will surely interpose the fact that E. B. Bigelow, the inventor of the modern carpet loom and one of the greatest of American inventors, could neither make one of his own machines nor the working drawings for it. His head was an amazing tangle of mechanical contrivances, but the draftsman and mechanic were indispensable to the successful evolution of them. This of course was a temperamental matter with him. We cannot change the fact that many inventors cannot express their own ideas; nor am I going to claim that any amount of technical training or of any other kind of training is likely to aid a so-called mechanical genius very much. Indeed, Mr. Bigelow never admitted to me at least, that a course in technology would have aided him; the nearest approach to such a concession was the remark, at the close of a busy forenoon spent in studying the Worcester school: "Well, I'll go home and consider how all this would have affected me had I begun here as a boy." I do not think he would have begun there or in any other school, for he was a genius in the best sense. A genius is a law to himself, the processes by which the mass of men must gain knowledge are strange and useless to him; generally he is a poor adviser in educational questions. He can never be educated in any sense in which the word is understood by ordinary men. Still, by a knowledge of the principles of mechanism and the methods of expressing and applying those principles, the ordinary inventor would secure to his use the benefit of his own inventions which somebody else so often appropriates, and would save the Patent Office much of its costly and superfluous rubbish.

No graduate of any school is at that time an engineer. The qualities of good judgment and efficient reason grow only in the atmosphere of experience. Hence no diploma can be regarded as meaning anything more than that the possessor has passed successfully the examinations that are set at any particular school. Graduates should begin at the bottom of their profession and their school training will tell best and most effectively in the rate of their advancement. They will advance more rapidly than others along the lines which are determined by their natural aptitudes.

The Almighty makes superintendents and leaders of men—no school can do this. But the training required for a superintendent must be that of his subordinates. All the best experience of the world sanctions this rule. A superintendent who has not had the training of the shop is as useless as Achilles without his weapons —he may seem and assume to direct and to lead, but he does not; on the other hand, the man who attempts to lead without natural leadership, however wise, is as useless as the weapons without Achilles.

The question how men shall best be trained for engineering was asked long ago before any practical result ensued.

The Marquis of Worcester, imprisoned in the Tower of London, 1645, working industriously upon his steam and water engines, cast eyes upon a lot which he could see from his window and instructed his agent to buy it, intending, he said, as soon as he was set at liberty to erect a school wherein boys might learn something of the principles of the mechanic arts. But he was never allowed the opportunity to carry out his idea.

There is an interesting letter from President Leonard Hoar, of Cambridge, to Robert Boyle, in which the good man, after acknowledging some favors from Boyle, discloses to him some darling projects of his own about the improvement of the course at the University and says: "I would have a large, well sheltered garden and orchard for students addicted to planting; an ergasterium for mechanic fancies, and a laboratory chemical for those philosophers that by their senses would cultivate their understanding; for the students to spend their times of recreation at them; for reading or notions are but husky provender." Boyle did not encourage the President, and his project slumbered for two centuries, but was at last substantially realized in the Lawrence Scientific School.

The first independent polytechnic school was the Ecole Polytechnique in Paris, founded in 1794. The Ecole Centrale followed, and during the first quarter of this century similar schools were established all over France, Switzerland and Germany.

In this country, the best appointed and on the whole, the most worthy of study as far as methods go is the Military Academy at West Point; then we have the Columbia School of Mines at New York, the Sheffield at New Haven, the Rensselaer at Troy, the Institute of Technology at Boston, the Stevens Institute at Hoboken and many others. These are examples of pure and independent schools of Technology, each with a special end of its own,

but possessing all the generic features of the class. They all arose from the demand for engineers in the arts of peace and of war. To this list must be added the state colleges of agriculture and the mechanic arts, several of which have made provision for effective teaching in engineering. The polytechnic school has always offered to the qualified average boy a good education based on drawing, the mathematics, the living languages and the physical sciences, tending to qualify him for immediate entrance upon the duties of an engineer. The course of study in a polytechnic school is determined by long experience and in all countries is substantially the same. It includes

Mathematics—Beginning with algebra and geometry, and proceeding through trigonometry, analytical and descriptive geometry, the calculus, theoretical and applied mechanics.

Physics—From the elements to the solution of problems, sometimes with laboratory practice.

Chemistry—With laboratory practice.

Language—The elements of German and French, (English replacing one of these in European schools) and the mother-tongue.

Drawing—Beginning with free hand and including perspective, orthographic and isometric projection, shades and shadows.

Geology and mineralogy as far as time permits. The other natural history sciences are necessarily omitted, except in special cases. In all these schools the instruction is given with a strong practical bearing, and generally the students learn the manipulation of the instruments used in surveying, and the more important of those used in physical researches.

It is necessary to remark at this point that technological schools do not include schools of design. There is a great interest in European countries and in the United States at the present time in what is called industrial art, meaning the study of form, color and ornament to renders tructures and manufactured goods intrinsically more beautiful, and to increase their value by this means. A department of drawing and design has a place in a school of technology, but engineering does not naturally include the work of a school of design.

But polytechnic schools as they were did not meet all the wants of the new era. Practical men detected a lack in engineers who had been trained without actual contact with a machine shop—there was a surplus of theoretical engineers and a dearth of practically efficient ones.

The principle of the division of labor resulted in making it next to impossible for a boy to find a place in any machine shop to learn the trade. The owner did not want him because it could not be in any way conducive to his business interests to employ a person ignorant of his business; and if he employed him at all he kept him on a single sort of piece-work, from motives of self-interest. Trades Unions conspired to keep out apprentices from shops, and so it came to pass that a boy could not get a good working knowledge of machine-shop practice except by stealth.

This demand for mechanical engineers with work-shop training, and the practical impossibility of finding a place for a boy in any good machine shop, led to the establishment of a polytechnic school in which a manufacturing machine shop is a prominent and thoroughly administered feature. This is the school known as the Worcester Free Institute.

This institution was organized under the influence of a belief that, after all that has been done in technology, there is still need of a system of training boys, broader and brighter than "learning a trade," and more simple and direct than the so-called "liberal education;" that while the boys should be thoroughly trained in all the essentials of a polytechnic course, they should also find a work-shop open where they could get all the essentials of a trade; so that upon graduating they should have sufficient knowledge of machinery and handicraft to enable them to earn a living while pushing their way up to the highest positions for which nature and their training had qualified them. It was held that not the least important of their qualifications for high positions is a good experience of the lower positions.

"It is the undoubting opinion of the managers of the Institute, and of all who have watched its operation, that the connection of academic culture and the practical application of science is advantageous to both, in a school where these objects are started together and carried on with harmony and equal prominence. The academy inspires its intelligence into the work of the shop, and the shop with eyes open to the improvements of productive industries prevents the monastic dreams and shortness of vision that sometimes paralyze the profound learning of the college."*

This school was opened in 1868, with the following fundamental ideas:

*Worcester Catalogue. P. 7.

1. That all mechanical engineers will find their account, in future, in going through a work-shop training.

2. This work-shop instruction may precede, accompany or follow the intellectual training, but for many reasons it preferably accompanies it.

3. The work-shop instruction is best given in a genuine manufacturing machine shop where work is done that is to be sold in open market and in unprotected competition with the products of other shops.

4. That in a course of three and a half years, working 800 hours the first half year and 500 hours a year thereafter, a boy beginning without any knowledge of mechanics can acquire skill enough to offer himself at graduation as a journeyman and will be found on trial not inferior to those who have spent the entire time of three and a half years in a regular machine shop.

5. That the work-shop practice must be a part of every week's work in the institution; that it shall be momentarily supervised by skilful men, and that the student must not expect or receive any pecuniary advantage from it.

6. That the question who shall be a superintendent or foreman or engineer engaged in designing or drafting machinery cannot be settled in any school—that being a question to be determined only by actual trial; because the discipline of the judgment by actual practice into which personal responsibility enters is vitally essential to a valid claim to the post of superintendent. Hence, it will follow that, while all receive the preliminary training requisite for engineering, many will not attain to it, but these will find a full reward for all their time and labor in superior intelligence as workmen—in being masters and not servants of the machines which they make or run.

7. A seventh principle was announced when the first class graduated, and has been inculcated into all their successors, viz: that the value of the education they have received will show itself in the rate of their advancement and will be easily detected by their employers, and that they should not be so much concerned, in seeking places, about great wages or high positions as about the chances ahead for advancement; indeed there might be cases in which they could well afford to work a while for a bare subsistence, such would be the value of their experience.

These principles have now been tested under as favorable conditions as could be desired for fourteen years, and this experi-

ence all goes to confirm them. No valid objection has been urged and no adverse criticism worth a moment's attention has been heard. The expense attending the proper development of this plan is the only difficulty in the way of its general adoption; but, within the brief period of its existence, the Worcester School has seen two great institutions founded on its plan, the Miller School in Virginia and the Rose School at Terre Haute.

Now since the principles just recited are to be the regulating force in the organization of this school, some discussion of their grounds is in place.

No argument is needed to prove that an engineer should have practical acquaintance with handicraft and with the machine shop in general. The great demand for men who have this qualification and the surplus of unemployed theoretical engineers, otherwise able and competent men who lack it shows that the point is well taken. The experience of the older countries sustains this view. It is found in Austria, so the Baron Von Eybesfeld (Minister of Public Instruction) told me, that there is a great excess of graduates of the polytechnic over the demand, and that he is now engaged in organizing a new kind of school in which workshop instruction shall form part of the course, so that the country may have some men for foremen and superintendents of works who are thoroughly versed in the practical details of machine-shop work. In carrying out this new policy, the latest phase, it will be noticed of technology, the great Gewerbe Museum has been organized and put in charge of Dr. Exner, a strikingly competent and efficient man. He has started two totally distinct sorts of schools: the first is substantially a half-time school, in which boys from the higher common schools work half the day and study the other half, receiving instruction according to the polytechnic plan as far as the time permits; the course being two years, these boys do not receive as much instruction as the polytechnikers, but they have the immense advantage of practical power in the shop, which secures them a living and adds to their value. Every stroke of work in the shops is done with reference to the sale of the articles, and no fact was mentioned oftener, or with more evident satisfaction by Dr. Exner in proof of the solid excellence of the school than that they sold in the first year a thousand gulden worth of their work. It is intended to multiply these schools so that they shall provide a great variety of mechanical practice (the two now in operation being devoted wholly to wood

working) and to extend the course to four years. When this has been done there will be in Vienna two schools in which all the principles of the Worcester Institute will be adopted and applied.

The second line along which the Austrians are moving is in cultivating what are known as cottage industries; this movement is so interesting that I shall venture to say something about it, though it is not immediately germane to our purpose. There is a marked tendency in Austria to concentrate population in large cities. The population of Vienna has grown from 800,000 to 1,200,000 within ten or twelve years and other cities show a great increase; this has occurred without a corresponding increase in the total population; the inference is that the growth of the cities is depopulating the villages—an unmistakable and alarming fact. Inquiry into the causes of this movement has brought out the fact that the peasants of these villages have lost the market for their baskets and other wares because their Swiss and French neighbors, who have had abundant schools of industry, have devised new and more attractive forms for the same wares. The peasants of Austria were unable to compete because, through their ignorance of design, they were confined to the old and unsalable forms, and with the fatuous haste so often seen, crowd the cities in the vain hope of bettering their lot. Dr. Exner, under the general direction of the wise and acute Minister of Public Instruction, has started schools for basket-weaving—by far the most important of these household industries. Half of the day is devoted to learning new and better ways of basket-weaving, and half to drawing and modeling in clay; the result being that the pupils learn how to do the things that are now in demand and are clothed with power to design whatever forms the future may suggest. Anybody may attend these schools who chooses to come to Vienna; for there only can a museum of examples be gathered sufficiently ample to enable the minister to multiply the schools so as to provide for other industries as well as basket-weaving. The hope is that the more intelligent young peasants will attend these schools and carry back to their villages the new ideas; this being done, a check will be put upon the tendency of people to leave the villages, because they can again be prosperous and happy where they are.

Upon the question whether workshop instruction should precede, accompany or follow the school training opinions differ, and a full discussion of the subject is impossible within the limits of this address. This subject occupied the attention of the Ameri-

can Institute of mining engineers through two prolonged and intensely active sessions in 1876, and the results are embodied in a valuable pamphlet which presents the views of the ablest engineers in the country. I will briefly summarize the facts and motives which seem to leave us practically no alternative but to incorporate the shop practice with the school-work. Boys fitting for a polytechnic school cannot leave the preparatory school younger than sixteen; if they are to get their shop-training before the polytechnic, they must spend three years at it and at the end of the time they will be rather too old to get the best advantage of the school, and miss the all important opportunity of applying their theoretical knowledge as they go along.

If, on the other hand, boys defer the shop till after graduating, they will find many excuses for slighting it or for not doing it at all. At the age of twenty, with a good knowledge of drafting and well disciplined faculties, American boys would be far more likely to turn into draftsmen or to take their chances in business than to submit to the dull routine of elementary shop-practice. Theoretically there is much to be said in favor of this plan, for it brings to the work-shop the trained powers of the school and makes the practice continuous. It is the plan of the Russians, in the Imperial Institute of Technology at St. Petersburg, certainly one of the best technological schools in the world, where the students, after a four years course in pure technology with the usual holidays and vacations, return on the first day of September and work in the machine shops till the first day of the following September, ten hours a day without vacations, and the results are very satisfactory. But the Russians can carry out such a system because the government controls the positions to which the students aspire and without which they must starve, and makes the fifth year of practice compulsory. Very few who have had much experience in teaching American boys believe that such a plan could be successfully adopted here.

There are many solid, positive reasons in favor of incorporating the shop-practice with the intellectual discipline. The period of a boy's life between sixteen and twenty-one is the period of sharp acquisition; ideas taken then remain in a special sense a part of the mental furniture forever. Probably no one, whose course of education is uninterrupted, acquires as much as between the ages mentioned, or retains what he acquires as long. It is an interesting fact that the enthusiasm which an American boy

cherishes for his college, an English boy feels for his school, where the training he most values was received. The American hurrahs for Yale or Harvard—the English for Eton or Rugby. The same would be true here were all our boys fitted for college at a few large schools and fitted as well. This being true, shop practice has an advantage it would otherwise lose in coming into this period.

Again, a man whose matured and furnished mind has laid hold of the strong problems of theoretical mathematics in school, and who finds himself on the threshold of manhood does not bend himself with just the same ease as an ungraduate to the elements of machine-shop practice. There is some advantage, too, in beginning shop-life in periods of five hours semi-weekly over ten hours a day; for less time proportionally is wasted. And finally, a great economy of the precious time of the students is secured because shop-work serves the double purpose of practice and of exercise.

Why the school workshop should not be a shop in a complete sense and not a mechanical laboratory or some other device for escaping the hard but necessary discipline of a shop, has not yet been stated. There is a difficulty in meeting the first cost and inevitable annual deficit, but if any other valid objection has been made to the plan it has escaped my attention. It offers every advantage of every other form of school-shop, with immense additions.

The advantages of a shop in which actual construction is made to aid in instruction are numerous; a few only can be mentioned. These boys are all hoping to be engineers, at least they may expect to become skilled workmen or draughtsmen. In any event the more the faculty of judgment is cultivated, and the more the boys realize the nature and extent of the difficulties that actual practice presents, of which the best theoretical knowledge gives no hint, the nearer they are to attaining the end they seek. We have seen that no graduate of a school is an engineer, but is in the best way to become one. Why not advance him as far as possible? If now the student's comprehension of the principles of engineering is clear and his weekly practice enables him to see those principles in action under conditions as like as possible to those which he will meet in real life, his entrance upon the life of an engineer will be an expansion of his school-life, and not an abrupt transition from it to a new mode of life. The more his work is subjected to the inexorable tests of business, and the more he feels in the use of his

materials just the same responsibility that rests upon an actual workman, the better he is. He must make the things that are to be used and not those contrived to suit the peculiarities of his temperament, the exigencies of his situation or the mere purpose of instruction. There is nothing that a student needs to make in a school workshop from which he cannot gain something if he puts the article into its final serviceable form.

Applying the stern test of serviceableness is the only way to know whether the things that have been made were worth the making or not, and is the only way to correct any tendency to visionary structure that is so apt to infect a school workshop, and to prevent that sublimation of common sense which is apt to ensue when responsibility for the correct use of costly materials is removed.

There is no merit or charm in work, considered merely as work; to work to produce something that some one else wants and cannot make for himself and is able to pay for is the stimulus of industry. All work in school-shops or any other will ultimately obey this law or else it will evaporate into exercise or sport.

Workshops into which the principle of construction does not enter are liable to exalt the importance of the purely literary aspect of mechanical knowledge. It is possible to know the five hundred and seven mechanical movements, to know the best cutting angles of saws, files and edge tools and not be a mechanic or be in the way of becoming one. This kind of knowledge is useful and attractive and desirable when it is not offered as a substitute for the dexterity that can be obtained only by the use of the tools. It will not do to regard our ancestors, the skilled mechanics, as fools. There is still but one way to learn to file and that is to file. The most expert filer I ever saw could not write his name. I do not think he could have filed any better had this simple accomplishment been added to his merits; he would have been a better and a happier and more useful man with more knowledge, but he did that one thing as well as it could be done at that time.

But this thought instantly suggests another of the greatest importance, viz: handicraft occupies a constantly narrowing place in the mechanic arts; machinery a constantly widening one. Every year adds to the number of trades from which the machinist has driven the craftsman. It is clear then that no training of boys for the life of mechanics is complete which does not make them familiar with machinery and machine-construction.

There is one demand sometimes made upon the school-shop which is unjust, namely, that it should pay its way. How can it pay its way when so large a part of its force is spent in teaching boys? If so many machine shops in this country, fitted up and managed with especial reference to money-making fail in business, or only make the ends meet by the most painful efforts, how can a shop one-half of whose effective force is spent in teaching boys, who cannot for the first half of their time produce anything salable, hope to pay its way? Teaching in school-shops costs as teaching elsewhere costs.

Many difficulties have been met and overcome, and many more which wore a threatening aspect ceased to be difficulties at all when the time came to deal with them. It is idle to spend time, therefore, in enumerating and discussing these difficulties. Those that remain are of trifling magnitude. It is better and more interesting to turn attention for a moment to another solution of this problem of technological education in the school at Moscow, in Russia, which was opened almost exactly at the same time as the Worcester school, and is now administered on the same general plan. I visited the school last October and will record a few observations upon it. The first room, into which I was shown by the superintendent of the shops, half the size of this chapel, was devoted to conferences with purchasers of machinery and would-be purchasers, who needed the aid of an engineer to design and draught machinery for special purposes; all the machinery thus designed is made in the school-shops. This room was filled with large drawing tables, on which lay working-drawings of machinery in various stages. The second room I saw was the engine room, where a twenty-horse engine was doing its best to drive the machinery of the shops, and later I saw a duplicate of this engine, every part of which had been cast and finished in the school-shops. The third rooms were the machine-shops, smithy and foundry, where a hundred workmen are employed in the double duty of manufacturing, and instructing the students how to manufacture; mingled with the workmen on that day were about sixty students. The fourth room was a store house in which was exhibited 60,000 roubles worth ($30,000) of machinery and machine tools, being the result of one year's work, and just brought back from the annual exhibition of the Industries of Central Russia. An equal amount made during the previous year has been sold. The fifth rooms were a series of smaller apartments in

which, for convenience, the students begin their practice. The method of teaching them is this: each year about eighty boys are received at an average age of seventeen and a half years; the course of study is six years, of thirty-two weeks in each year; for the first, second and third years, the boys all work in the shops fourteen hours a week, or 448 hours annually; for the fourth, fifth and sixth years, ten and a half hours a week, or 336 hours annually, so that they work an aggregate of 1344 hours in the first three years and 1008 the second three; the rest of their time is occupied with the ordinary curriculum of a polytechnic school. The practice of the first three years, or rather more than half of the whole is spent in preparing for that of the second three; i. e. for the first half they do not attempt any manufacturing, and for the second half do not do anything else.* In these rooms the boys were filing, forging, sawing, turning, etc., each as fast and well as he could, all the boys in any one room being responsible to the foreman of that room, whose duty it is to provide work for each boy and decide upon its quality. Each boy is pushed as far as possible in the time allotted to each room regardless of his mates. The work done in these rooms is mainly thrown away, though some is saved for models.

But the boys are just as much in need of direction and efficient skill when they emerge from the elementary shops as they were before, and it never occurs to the faculty that one of these boys is fit for any shop but their own until his course is completed, any more than an ordinary college faculty regard sophomores as ready to study theology. The boys in the elementary shops have free access to the manufacturing shops, see where every piece they are making fits and how it is used—they do everything in a manufacturing atmosphere, and every boy who passes the requisite examinations, with very few exceptions, passes into the manufacturing shops. The Moscow school-shop is a great manufacturing establishment and, if the manufacturing element were removed, the school would be either revolutionized or extinguished. The elementary shops are a convenient, and for that school, serviceable and economical device for doing what all school work-shops must do, separating unsalable work from salable, and keeping apprentices at work by themselves though in full view of and in full co-operation with the manufacturing shops till they have skill enough to

*The Superintendent said that if one of the boys in the preparatory room made anything salable they did not hesitate to sell it.

begin to do salable work. My conviction is, however, that the results are not what might be expected; for the work done by these boys at the end of their first half year course, or after 1344 hours practice, does not compare favorably in excellence with that done by the boys at Worcester after their first half year, or 800 hours, and candor compels me also to say that the work of the graduates at Moscow is at least not at all superior to that of the Worcester men.* The graduates of this school and of that at St. Petersburg compete for the same prizes and all obtain good positions in manufacturing establishments.

Some statistics will show the thoroughness of the discipline of the school and the importance attached to it by the government. The government appropriates 250,000 roubles, or $125,000, annually to this school (and the same to St. Petersburg). The number of Professors is fifteen, of Lectors ten, all others three. The tuition is 150 roubles, or $75.00, a year. The floor space at Moscow is not less than 400,000 square feet—that of Worcester is 50,000.

A set of plans of the building will soon be found in our library.

It adds great force to Russian examples and precedents to know why we find their polytechnic schools of such rare and unsurpassed excellence.

The popular impression of Russia does her great injustice. The educated Russians are a highly educated and accomplished people. Part of this intelligence is due to the intermixture of the German population, which began soon after the death of Catharine and has continued to the present time. Now, when the Russians began, about fifty years ago, to attend to the development of their internal resources in a scientific manner, they started in the most sensible way, by sending commissioners to study the systems of technological education of Western Europe. These men winnowed Europe for ideas. These ideas they carried to Russia and expanded into schools which surpass in completeness of equipment and affluence of resources all others in Europe, with the possible exception of the Ecole Polytechnique, in Paris. They had the money to give German ideas of education an expansion and development of which the Germans, in their poverty, never dreamed.

* The work done by the graduate-mechanics of St. Petersburg is especially interesting because it is evidence of the advantage of well-disciplined faculties in acquiring skill in handicraft.

Russia is the lee shore upon which the choicest educational pebbles may be gathered. In studying Russia one sees all European technological education epitomized.

And since the notice of these inauguration exercises was printed I have news that the Imperial Institute of St. Petersburg has stretched her hand across the wide waters to give us a welcome into the fraternity. Notice has come that a box of examples of the work done there and a collection of drawings has been shipped as a present from one of the oldest to this, the youngest of the polytechnic schools.

But I must hasten to complete this exposition of principles. The fourth fundamental at Worcester is that in a course of three and one-half years a boy, by working 800 hours the first half year and 500 hours a year thereafter, can gain as much dexterity and be as fit to offer his services as a journeyman as he would be had he worked three and one-half years steadily in a modern machine-shop. The experience of two hundred graduates of the Worcester school, and the opinions of the manufacturers in whose shops they have found employment, establish the fact. Some of the reasons for this somewhat paradoxical result are that in an ordinary machine shop a boy must spend his time in his employer's interest and not in his own, and only a small portion of that time is devoted to teaching him manipulation; in the school-shop the time is wholly used in teaching. Again, the student-apprentice is under daily training in school and comes to his work with alert faculties and acquisitive powers constantly growing stronger. This is especially true with reference to his weekly practice in free drawing, a study which tends to develop and train the sense of form and proportion, the very training that a mechanic most needs. And, again, the work of the student is done under the eye and with the ready assistance of a skilled workman whose duty it is to teach him, by precept and example, all he can learn. Meantime, while he has been getting his manual dexterity, our student-mechanic has obtained a good education. The remaining principles require no further explanation.

It will now be asked what may the graduates of this school be expected to do. To this I reply by reciting what the graduates of the Worcester school have done: Occupations of graduates—

Partners in business firms	23
*Superintendents	16
Chief Engineers	3
Division Engineers	5
Assistant Engineers	16
Civil Engineers	20
Draughtsmen	49
* Mechanical Engineers	10
*Machinists	13
Foremen	8
Teachers	17
Chemists	12
Advanced Students	4
Designers	5
Others, mostly engaged in manufactures	45
	246
Deceased	9
Total	255

More than ninety-five per cent. of the graduates are engaged in occupations for which their training at the Institute specially prepared them.

In the Rose school the following modifications of the Worcester plan will be attempted:

1. The course of study will be four years instead of three and a half.

2. The practice will be concentrated in the first year and diminished in the fourth, so as to allow time for more instruction in machine-design.

3. While the same subjects will be taught, perhaps more attention will be given to the humanities.

4. A different view will be taken here of the profession of civil engineering from the one usually held. The young men who propose to be civil engineers will spend a part of their practice time in the machine-shop.

Civil engineering cannot easily be separated from mechanical, because the most important business of a civil engineer nowadays is not surveying and mapping but bridge and building-construction, the setting of water-wheels and other engines, and such like undertakings which involve a knowledge of mechanics; so that two or three of the best so-called civil engineers in the country have given it as their judgment that a course in mechanics includ-

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*Many of these are "Master Mechanics."

ing workshop instruction, is the best way to prepare for the practice of civil engineering.

But on the other hand, the building of new highways and railroads still goes on and calls for a certain number of young men who are expert in the use of the transit and level (especially in railroad problems) who know how to draw and who understand mensuration; hence, training for this sort of employment cannot be neglected in a polytechnic school. It would conduce to clearness to call such work Topographical engineering.

An added consideration of some weight in favor of retaining a distinct department of Topographical engineering is that many of the young men who frequent technological schools have no taste or aptitude for mechanical work, and some have not the requisite physical vigor for it, whose fitness for success in field-work or in mapping is unquestionable. But it will be clearly advantageous to all to have some workshop practice. No changes will be made except such as reason and a large experience show to be desirable and advantageous to the student.

But a healthy child wants food. An adequate beginning must be sustained by continual contributions in order to good progress. We want the sympathy and patient consideration of the community. We want books, apparatus and models constantly in excess of the resources of our funds. The example of our founder is worthy of attention and imitation.

The machine-shop is ready; a reference library will soon be on the shelves; a cabinet of minerals is on hand; ample models are ready for the proper equipment of rooms for drawing and design; the bricks for a new building for a chemical laboratory are now lying in the yard; apparatus for chemistry, physics and field work is in the building or provided for; commodious recitation and lecture rooms are ready when wanted.

I hope also, in course of time, to collect models and examples of the best mechanical devices, and also of leading manufactures. These collections of models play a very important part in European technological schools, and for obvious reasons. Indeed, the outlay in some cases is enormous and would be insupportable did not manufacturers find their account in placing here examples of their best work. At Chemnitz I saw two good examples of this class: one a perfect working model of the Hartman locomotive, which cost $3,000, and the other a large working model of the

Merkel stationary engine, worth $250—each presented by the manufacturer.

In order to any effective use of these resources two things are vitally requisite: good teaching before the students enter the Institute and good teaching afterward. It is on the whole, a mistake to suppose that fitting for the polytechnic is essentially different from fitting for any other form of manly labor in this world which depends upon a sound, instructed brain. Technically, boys will be examined for the present in English grammar, geography, United States history, arithmetic, and algebra as far as quadratic equations; but these are the essentials of any success at all in the polytechnic; the more a boy knows before he comes the broader and deeper his success will be. The polytechnic is a professional school and must concentrate itself upon its own special work; but the broader the base on which it builds, the more massive the structure that can be reared. Whether the polytechnic course shall rear an obelisk or a pyramid depends on the preparation of its students.

Men are born as ignorant as they ever were and the same steps from ignorance to the elements of all knowledge must be taken by every one. This work usually occupies the first fifteen or sixteen years of every human life.

It is very desirable that every boy who presents himself for admission here should have at least a full high school course; if he cannot get that, let him make the closest possible approach to it. Youth once passed, the opportunity for acquiring the rudiments of knowledge is usually gone forever. And eye hath not seen nor ear heard a sadder thing than the lament of a man who, amid the emergencies of life, suddenly confronts his need of some simple knowledge which he might have got for the asking in his youth.

The greatest solicitude will be ever cherished here about the quality of the teaching. It is not intended that students shall find more assiduous or competent teaching in the various branches of the course than will be constantly found in this institute.

But there is one peril and annoyance to which the new polytechnic is subject: handicraft in school never having been used before except for reformatory purposes, the impression gets abroad that the institution must lower its intellectual standing to raise the handicraft. I do not know an institution in this country except West Point where boys achieve as much good work or are better

prepared intellectually for effective service as engineers than they are at Worcester. We propose to give the same training here.

If what has now been said seems to have a too exclusive bearing upon the study and practice of mechanics it is because this is the leading department, and presents the only novel and difficult features of our enterprise; but there will be departments of civil engineering, physics, chemistry, and design organized on the same general plan; the studies will be the same in all departments—the practice different according to the purpose for which it is intended. These departments naturally group themselves; for chemistry, physics, and drawing must be taught to mechanics, and the additional expense required to give practice in each of these departments to those who prefer it to mechanical practice is very small. The outlay required for civil engineering practice is justified by the demand.

Later in our enterprise a department of Mining Engineering may be organized; and in the department of physics special attention will be given to electrical engineering. All this will come about in due time. It will be observed however that only one kind of practice can be profitably taken by any student, during the course. Full particulars in regard to all these matters will be seasonably given.

If this account of the origin and method of the technological school be correct, it is obvious that it is no longer an experiment, that it fills a gap, that it is a natural, inevitable, every way desirable and welcome concomitant of modern civilization. It does for the industrial arts what the colleges have so well done for the learned professions by fitting men in a carefully planned course of study for the intelligent discharge of their duties.

The polytechnic seeks to work as an ally of the old classical college, and hopes that her old friend may find something to her advantage in studying the economy of force which prevails in the methods and results of the new comer. The polytechnic does not sustain any organic relation to the college such as the academy has on the one hand and the professional school on the other; yet in a deeper sense it sustains a very important relation to it. Whatever tends to increase or foster the desire for knowledge tends at once to foster all institutions whose object is to promote knowledge. Every new institution tends to increase the interest in the old—provided the old are worthy. Of course, I do not mean by "new institutions" repetitions of old types, such as the multiplication

of small colleges, for this is generally an evil rather than a good (except in new States), but I mean new institutions, like polytechnic schools, that strike their roots into new soils and make what was once a desert blossom as the rose.

Technical schools have not affected the colleges unfavorably in the matter of attendance; for in spite of the crowds that have flocked to their doors, the classes in the colleges have steadily increased. More new colleges have been founded during the period of the rise of polytechnic schools in this country than in any similar period before; the old colleges have received munificent increase of their resources and have more than held their own in the matter of attendance, and all the students attending the state universities in the course of Liberal Arts may be reckoned as a solid addition to the ranks of the college.

For obvious reasons the polytechnic school flourishes best when separate and distinct from the college; but the more it flourishes the more it will directly benefit the college by providing for the instruction of the youth who demand the so-called "practical courses" and thus leave the college free to pursue her own legitimate work. Towards all forms of knowledge technology is hospitable, and towards all who know, engineers are affectionate. The study of science in a teachable and reverent spirit does not beget intolerance or bigotry. Science inculcates hatred of pretense, and is intolerant of dogmatism; but mindful of the counsel of her greatest disciple, she utters the solemn words of Bacon:

"This also we humbly beg that human beings may not prejudice such as are divine, neither that from the unlocking of the gates of sense, and the kindling of a greater light, anything of incredulity or intellectual night may arise in our mind toward Divine mysteries."

The day has forever passed when the old idea that the study of Latin, Greek and the humanities is the only education. The definition of an educated man will bear still more expansion, but it has broadened rapidly, during the last quarter century. *"The vulgar argument that a study of the classics is necessary to make a gentleman is beneath contempt. Honor and gentleness are not a dye or a lacquer, but warp and woof. It is true that a certain social considerattion attaches to persons who are supposed to know Latin and Greek, whether they are gentlemen or not;" but society

* President Eliot.

is rapidly adapting itself to the new era in which men and women are to be taken for what they are and not what they are said to be.

It is an unique and interesting fact that most of the polytechnic schools have been founded and endowed by private benefactors. The colleges, seminaries and academies have depended at times upon legislative fostering. Hardly a session of a State legislature passed prior to 1873 without considering some bill in aid of an educational institution. But the strong point about polytechnic schools is that the enormous expense of founding and administering them has been provided in most cases by individual citizens who knew their value. The Ecole Centrale in Paris, next to the Polytechnique the best in France, was the joint product of the brains of Dumas, Pictet and Ollivier and the pocket of their friend Lavallee, who paid all the expense of starting and running the school for five years, and at the end of that time presented it to the government. In this country Lawrence at Cambridge, Van Rensselaer at Troy, Sheffield at New Haven, Stevens at Hoboken, Boynton, Washburn and Salisbury at Worcester, Rose at Terre Haute, Case at Cleveland and many others have said in tones which many generations will hear what they think of the value and importance of technical education, and have made the State the recipient and not the nurse of their bounty.

In the city of Glasgow, nothing impresses a traveler more amid all its teeming industries than two monuments, one of great height and majesty to John Knox, the other a simple tablet in the wall of the cathedral to the memory of George Bailey who founded unsectarian schools and libraries for the operative classes.

The city of Terre Haute will cherish none of her treasures longer than the memory of her princely benefactor; but her choicest heritage is the inalienable right to put upon his monument with a change of name the inscription which can be read at the grave of Copernicus in Warschau:

To Chauncey Rose, our Fellow Citizen.